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Research Article

Ontology Based Knowledge Management System Design for Organic Farming

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Abstract: In the current agricultural system, information is often gathered manually, and farmers make decisions based on their judgment. Occasionally, they seek advice from experts and extension officers. Numerous information systems have recently emerged, offering insights into organic farming practices. However, this information is dispersed across various contexts, formats, and media on the Internet, making it challenging to access. Utilizing ontology with a conceptual framework allows for the thorough and detailed formalization of any subject area. This research aims to gather, store, and supply organic farming information to current and prospective software developers interested in creating applications for farmers. It uses information extraction and development methods to create an ontology-based information extraction system for organic farming. The knowledge base was constructed using the Protégé editor. Meanwhile, Hermit was used to ensure the ontology's consistency by using reasoning techniques and to submit queries to verify their accuracy. These queries are formulated in description logic and evaluate the ontology's ability to answer farmer queries by presenting instances of competency questions from the Description Language query interface. The responses generated by the ontology were promising, indicating its effectiveness as a knowledge repository.

Keywords: Ontology, Organic Farming, Crops, Soil Productivity, RDF

Introduction

Traditional agriculture, in several specific types throughout history and geography, is the oldest type of agriculture that has existed for millennia. All varieties of traditional agriculture today are considered to be "organic agriculture," although there were no inorganic practices at that time. Today, organic farming plays an important role in mitigating various health problems due to the consumption of unhealthy grains and food. With the advancement of technology, farmers are leveraging new ways to increase crop yield by using many pernicious chemical fertilizers and pesticides that stifle soil productivity in the long term (Gokhberg et al., 2019). The government should spend prodigious funds to uplift the agriculture sector in our country. India has been more agriculturally centric since the antediluvian. The country will have to develop tools and techniques for augmenting crop production with organic farming, avoiding chemical fertilizers and pesticides. Around the globe, many countries started to switch to organic farming. An organic movement first arose in the 1930s as a counter-reaction to the growing reliance of agriculture on chemical fertilizers and pesticides during the Industrial Revolution, which brought inorganic practices most of which were poorly conceived and had negative impacts. Farmers, philosophers, and scientists who questioned the sustainability of widespread use of these technologies, for example, objected to the use of chemically produced agricultural inputs such as urea and DDT. Early in the 20th century, a time marked by growing reliance on these new synthetic, non-organic methods, organic farming first surfaced in the modern renaissance. Organic farming began with the ideas of certain 1930s scientists like Rudolph Steer, J. I. Rodale, Lady Eve Balfour, Sir Albert Howard, and many more. From the organic movements covering Great Britain as well as continental Europe between the 1920s and the 1950s, modern organic farming in the United States started. Recent socio-economic development has been fueled by the universal implementation of Information and Communication Technology in both government and non-governmental organizations. This revolution has enhanced livelihoods positively and facilitated the emergence of vibrant knowledge societies. With information communication technology and related technologies continuing to converge, these societies have become more capable of effectively producing, accessing, and utilizing information.

Government and non-governmental institutions' transition to Information Communication Technology has contributed to enhanced living standards and the emergence of information and knowledge-based societies. Through the continued convergence of new information communication technology and related technologies, the ability of these new societies to return, acclimatize, and use data has developed immensely (Okello et al., 2013). The development of agriculture is based on the need for accurate, relevant, and timely information, which is extremely critical and cannot be emphasized enough (Relebohile and Keregero, 2019). In the majority of established countries, farmers have agreed to precision agriculture to boost farming production through the widespread use of information and communication technology in climate prediction, farm machinery, irrigation, and soil investigation (Desai et al., 2024). Sufficient effort, however, has not been directed towards obtaining, packing, and sharing brief organic farming-related knowledge to existing and potential system developers interested in developing applications specific to farmers (Bruinsma 2017). Using biological methods and management strategies to improve soil health using soil organic material, nutrient cycling, water, and carbon concentration/storage, organic farming is a fresh approach. It maximizes the well-being and output of several groups in the agro environment, including soil organisms, humans, plants, and animals (Canadian Agri-Food Policy Institute, 2019). In 2015, Francis notes organic farming as "producing the crop, animal, and other products without synthetic chemical fertilizers and pesticides, transgenic species, antibiotics and growth-enhancing steroids, or other chemicals." Organic farming aims to create a compassionate, integrated, economically and environmentally sustainable agricultural system, mostly depending on renewable resources, mostly from the land (Deshmukh and Babar, 2015). The method of organic farming guarantees farming sustainability. Therefore, farmers will benefit greatly from the simple availability of pertinent and succinct information in increasing their production and guaranteeing sustainability for the next generations. Although growth in digital libraries and increased Internet access have made access to current information sources simpler in recent times, locating, extracting, and collecting pertinent information from this data pool is progressively becoming a challenging chore (Abayomi-Alli et al., 2021). Extraction of information is not a simple chore. Natural language's intricacy and uncertainty make information extraction a somewhat difficult chore. For instance, the same truth might be stated in several publications or knowledge stores using different languages. Ask because natural language is inherently unclear and complicated.

For instance, the same information might be expressed in several ways depending on the language used in different papers or even knowledge databases (Gutiérrez et al., 2016). Such material is delivered as organized, formless, free-text documents, multimedia files, pictures, etc., thereby making search or analysis challenging (Zhu et al., 2011). Therefore, a good and efficient method of extracting organized information from free-text data is becoming more and more necessary to expose pertinent and valuable knowledge. Information extraction is the search for a pre-defined collection of ideas inside a given domain, excluding undesired information. A domain is a collection of writings covering a certain informational requirement. It's a method of obtaining ordered factual knowledge from unorganized text (Chang et al., 2006). It helps consumers search for information from a lot of relevant material. Using ontology has helped knowledge retrieval by formal and explicit domain concept specification; consequently, knowledge extraction is a super discipline of ontology-based knowledge retrieval (Wimalasuriya and Dou, 2010). Information retrieval is ontologically reliant, supporting and guiding algorithms for pertinent and efficient knowledge extraction; it is not necessarily an exact technique or procedure (Alejandria et al., 2019). A normal and official explanation of farm science ideas is agricultural ontology. Like other agricultural methods, organic farming is practice- or action-oriented since information communication technologies document and communicate implicit and explicit knowledge (Gao et al., 2012). An enormous amount of raw data is created from agriculture information systems, drones, IoT devices, official bulletins, reports, journals, publications, social media data, participatory documented practice from farmers via interviews, etc., precision agriculture, and sensors (Jiang et al., 2020). The raw data is meaningless and useless without the appropriate background and data aggregation with other sources of data. As such, it is of little advantage to the farmer (Drury et al., 2021). The semantic web allows ontologies to improve interoperability across several diverse information sources or systems, including suitable background, meaning, and data aggregation. (Roussey et al., 2010a). Automated reasoning of agricultural data will improve the platforms designed using ontology as its semantic schema. It will simplify the process of establishing important linkages among the ideas included in the data and increase the possibility of assigning appropriate classes to every cell in the domain knowledge, independent of the data variability. Through the semantic web, ontology will improve interoperability across several diverse information sources or systems (Goldstein et al., 2019). Ontologies in agriculture include exchanging vocabularies and integrating data, improved search and knowledge discovery, greater system interoperability, constant decision support, and autonomous decision-making. Because of the several advantages and relevance of organic farming knowledge exchange among agricultural practitioners, as well as complicated linkages among its principles (Walisadeera et al., 2015). This paper is a bid to build an effective ontological-based platform to govern organic farming knowledge by gathering valuable knowledge regarding the organic farming industry, avoiding disinformation and misleading information of organic farming practices by effective coordination, storage, and reuse of organic farming knowledge, and bridging the gap between farmers and the organic agriculture industry experts to facilitate easy adaptation of organic farming practices.

Literature Review

Knowledge management is the process of capturing, building, disseminating, and utilizing organizational knowledge (Deshmukh and Babar, 2025). Knowledge management is an interdisciplinary approach to organizational goal achievement through the appropriate utilization of knowledge. A knowledge management system facilitates rapid and effective sharing of knowledge between people. An ontology is an explicit formal high-level specification of a certain knowledge domain. It is a description of an explicit and formalized shared conceptual model (Abayomi-Alli et al., 2021). Ontologies are on the verge of becoming a foundational technology to support the semantics-based processing of knowledge. Ontologies are employed to lay a foundation for facilitating the interchange of an exact sense in communication. Meaningful knowledge is leveraged by different applications (e.g., knowledge management, e-business applications). Ontologies have become extremely helpful in knowledge management since they are information retrieval applications, information systems, and system modeling, and semantic storage and retrieval of knowledge is easier with them (Gutiérrez et al., 2016). In ontologies, knowledge is expressed in a machine-readable and interpretable manner. The idea of a machine interpreter is that a computer or software agent may deduce the links between ideas automatically. Ontology reasoners might also provide further capabilities such as knowledge discovery and automated classification. Ontologies find various applications in the field of knowledge management, not just in content distribution but also in information staging and content development. Knowledge and information are arranged depending on a shared common lexicon using ontologies as repositories.

Agriculture Ontology

Studer et al. (1998) created a knowledge base for an ontology of agriculture that can be applied to the development of intelligent agricultural systems. This ontology contains fundamental concepts from the agricultural domain, in addition to sub-domains pertaining to geography, the IoT, business, and other knowledge gleaned from a variety of datasets. Any user can easily understand the agricultural data links between each other when using this ontology, and these links can be collected from a wide variety of data resources. Kaewboonma and Tuamsuk (2017) presented Ontology-enabled IoT extracts attributes. Counting critically post-harvested Sekai ichi apples is easy. The hierarchical Post-Harvest model prevents post-harvest losses and deficiencies and quickly identifies trash to keep agriculture healthy and separate from its surroundings. The lower, middle, and higher processing techniques were used for separation. By focusing on identifying a negative shift, the intermediate level is being generalized. Ngo et al. (2018) generated and integrated citrus production data. The Eight-Point Charter of Agriculture divides citrus knowledge into eight areas and develops links within each category. The citrus production knowledge framework has eight categories and links. Sanjeevi et al. (2021) recommended a Tamil–English CLIR method. This method obtains pages in English by translating Tamil queries. To resolve the Tamil question ambiguity, a word meaning disambiguation module was deployed. An automated English ontology is used to address English inquiry ambiguity. To translate Tamil queries into English, the authors created a morphological analyzer, a multilingual dictionary, and a named entity database. Wang and Wang (2018) offered a self-contained reference strategy to stimulate semantic web study on agricultural concerns. Thenmozhi and Aravindan (2018) suggested proposing a general ontology-based data acquisition paradigm to construct MVC-based data collection forms for agricultural open data platforms. OWL2MVC, which uses the Hazelnut Ontology, was created to show how well the suggested model generates data collection forms. Because model construction follows ontology class selection, OWL2MVC Tool users may easily and independently create data gathering forms. Drury et al. (2019) provided an ontology-based knowledge base for the purpose of storing information regarding the various components that make up soil composition. The ontology supplies a structured and formalized body of knowledge, which is then mined for various patterns. As a result, recommendations are made regarding the types of crops and the soil compositions that are best suited for growing crops. Aydin and Aydin (2020) presented a search engine's user-centered ontology construction strategy. The search engine helps farmers and advisors identify relevant research. Subject matter experts, advising practitioners, and stakeholder groups participated in 10 European case studies. Aydin and Aydin, (2020) outlined a plan for the creation of an ontology that is specific to the agriculture domain. The strategy that has been suggested will work in two stages. Domain-dependent regular expressions, as well as natural language processing, extract agriculture-related words in the first step. The writers will next identify semantic links between extracted words and sentences. RelExOnt, a rule-based reasoning algorithm, is suggested for the task. Ingram and Gaskell (2019) explored system as well as software engineering quality ideas to adapt and improve ontology engineering principles. The authors developed an ontology quality strategy to help developers construct high-quality ontologies and viable ontology-driven DSSs. The approach was shown using an agricultural use case. Kaushik and Chatterjee (2018) presented two objectives. The first purpose is to create a natural language interface for the ontology based on agricultural fertilizers, and the second is to design and develop it. An ontology takes a long time to create since it requires professional and physical labor. One of the key aims of ontology design and development in agriculture is to make it usable in real-world circumstances. The generated ontology's real-time applicability will be enhanced by integrating it with crop or soil ontologies. An interface that employs normal language to connect with the ontology provides information to the user. Wilson et al. (2022a) presented the content and features of the platform, including the additions that were made to the technology that was initially developed. Five primary agronomic use cases helped create and embed the initiative in the community. AgroPortal is a powerful and feature-rich resource for the agronomic domain that builds on biomedical knowledge and technology. Malik et al. (2018) presented a suggestion system to simplify pest identification and treatment. Their suggested system relies on a crop-pest-treatment ontology. Jonquet et al. (2018) created an iterative quality technique by analyzing ontology engineering and software engineering quality theories and applying them to quality concerns. The authors show their technique and explain how different ontology quality theories relate to it. A use case in agriculture shows how the technique may be utilized in real life. To refine and prove the technique, further trials are expected in the future. Lacasta et al. (2018) discussed the ways in which the structure of a created ontology may be maintained by collaborative efforts. By storing the ontology on a central server, this work employs a synchronous collaborative research methodology. Through intuitive web-based interfaces, collaborative partners have the ability to make changes to the ontology and ensure its continued upkeep. Every user is aware of the changes that are made to the ontology in real-time as they occur, since the ontology is stored in a single location. The sorts of modifications drive the generation of different versions of the ontology. If the change would have an effect on the previous versions' compatibility, a new version will be developed; otherwise, the existing version will be updated. The semantic versioning standard is used so that various versions may be distinguished from one another. The implemented system undergoes independent validation as well as evaluation with the assistance of a user group. Wilson et al. (2022b) focused on presenting the environment and the states of the robots in a smart space while they are working together to solve a task. Gazebo and ROS model, and see the interaction process. The authors described robots' equipment and physical traits in their ontology. Fuzzy sets assess some ideas to allow robots to interact differently. An ontology-based insect pest management decision support system was presented by Katty Lagos-Ortiz and her colleagues (Rathnayaka et al., 2018). The system was designed for use with sugarcane, rice, soya, and cocoa crops. This system makes use of Semantic Web technologies to record the knowledge of experts and applies semantic reasoning in order to identify insects that cause damage to crops. Teslya et al. (2021) proposed a computer model, Indoor Plant, for indoor agriculture. The analysis of context histories is utilized by the model in order to provide intelligent generic services. These services include the prediction of productivity, the indication of potential issues that may arise with cultivation, and the provision of suggestions for improvements to be made to greenhouse parameters. With hydroponic production data gathered over the course of seven months from the cultivation of radicchio, lettuce, and arugula, In door Plant was put through its paces in three different situations that mimicked the day-to-day activities of farmers. Lagos-Ortiz et al. (2018) proposed an innovative method for identifying emerging technologies in specific industries and researching how they will evolve in the future. Based on text-mining research, the first stage presents the ontology of developing technologies in global agriculture and food. Text-mining methods pooled these technologies in the second stage. These were:

(1) Technical market projections
(2) Their potential to solve sectoral and national problems

This research, supplemented with big data, identified opportunities for Russian aerospace and defense science and technology development. Martini et al. (2021) developed an architectural model utilizing Partial Least Squares Regression to assess soil fertility and productivity based on history.

Research Gaps

After conducting a complete study of various research that has been carried out in the context of ontology used in agriculture, along with organic farming features, we found that there are some research gaps where there is a scope for further research. The shortcomings of our study are listed as follows:

- Despite the fact that numerous techniques have been established for organic farming devices, formal procedures for interoperability in technology, as well as standard data formats, are still lacking
- The existing ontologies do not cover all the keywords and aspects needed for implementing semantic interoperability in the organic farming sector
- There is a need for a comprehensive ontology for agriculture that provides an effective knowledge base that covers most of the concepts, instances, and relationships related to organic agricultural farms

As ontology is a rapidly growing technology, new concepts are continually being added; hence, an adaptive ontology updating is required to ensure the reliability of data. An effective solution is needed to assist the farmers from the start to the end stage of crop production with semantic reasoning. There is a scope for further improving the performance of yield prediction models by putting extra efforts, such as using additional weighted parameters, adding new loss functions, etc., to the existing models.

Materials and Methods

In the proposed framework of an organic framework, we have constructed an ontology based on AGROVAC ontology and using protégé framework, which is an open-source tool to create an ontology. We have constructed an ontology by considering various classes like Crops, Helpful Organisms, causes of diseases, equipment storage methods, and all necessary classes for organic forming, as given in Table 1. We created instances for each class and linked the classes using various data and object properties as given in Table 2. We have populated the ontology using a sample organic farming dataset of 121 instances and 15 farm types. After constructing the ontology, we posed SPARQL queries to retrieve the data for organic farms.

Proposed Framework

Organic farming ontology is constructed by considering a sample data set that contains 18 different types of organic farms along with the required soil pH (Helfer et al., 2020), water levels, and nutrient content, as well as the pests that affect those plants. And we identified the concepts of organic forming from various materials and by conducting a questionnaire among the farmers. We identified various concepts like post and pre-planting operations, pest control, soil selection, ecological factors, water requirement, and various crops, which include fruits, vegetables, legumes, and others. We constructed an ontology for our proposed method in protégé by considering various classes like crops, planting operations, diseases and their causes, farm tools, and irrigation, etc. The methodology is shown in Fig. 1.

Table 1: Classes and Subclasses

S. No	Category	Subcategories
1	Crops	Bulbs, Cereals, Fruits, Grains, Herbs, Leafy Greens, Legumes, Oil Crops, Root and Tubers, Vegetables
2	Helpful Organisms	Annelids, Beneficial Bacteria, Predatory Insects
3	Causes of Plant Diseases	Arachnids, Bacteria, Fungi, Insects, Nutrient Deficiencies, Parasites, Pests, Viruses
4	Environmental Influences	Rainfall, Climate Conditions, Sunlight, Water Availability
5	Agricultural Equipment	Cultivation Tools, Pest Control Implements, Harvesting Tools, Irrigation Systems, Planting Equipment, Post-Harvest Tools
6	Eco-Friendly Methods	Companion Planting, Proper Plant Spacing, Seed Viability Testing
7	Sowing Techniques	Intercropping, Cover Cropping, Nursery Methods, Precision Planting, Minimal Tillage, Seed Testing, Transplanting
8	Post-Sowing Practices	Harvesting, Pest Prevention, Post-Harvest Handling, Structural Support, Supply Chain Management, Thinning, Water Management, Weed Suppression
9	Pre-Sowing Considerations	Site Selection, Seed Viability Assessment
10	Soil Health & Properties	Drainage Capacity, Soil Fertility, Soil Condition, Soil Composition
11	Storage Techniques	Storage Bags, Bamboo Containers, Barns, Baskets, Drums, Drying Racks, Dryers

Table 2: Data Properties

S. No	Domain (instance)	Type	Data Property	String value
1	Apple	Fruit	Has nutrient content	2.5
2	Apple	Fruit	Has SoilpH	6.5
3	Apple	Fruit	Requires water	40
4	Broccoli	Vegetable	Has nutrient content	2.1
5	Broccoli	Vegetable	Has SoilpH	6.5
6	Broccoli	Vegetable	Requires water	25
7	Lettuce	Leafy Green	Has nutrient content	1.0
8	Lettuce	Leafy Green	Has SoilpH	6.5
9	Lettuce	Leafy Green	Requires water	25

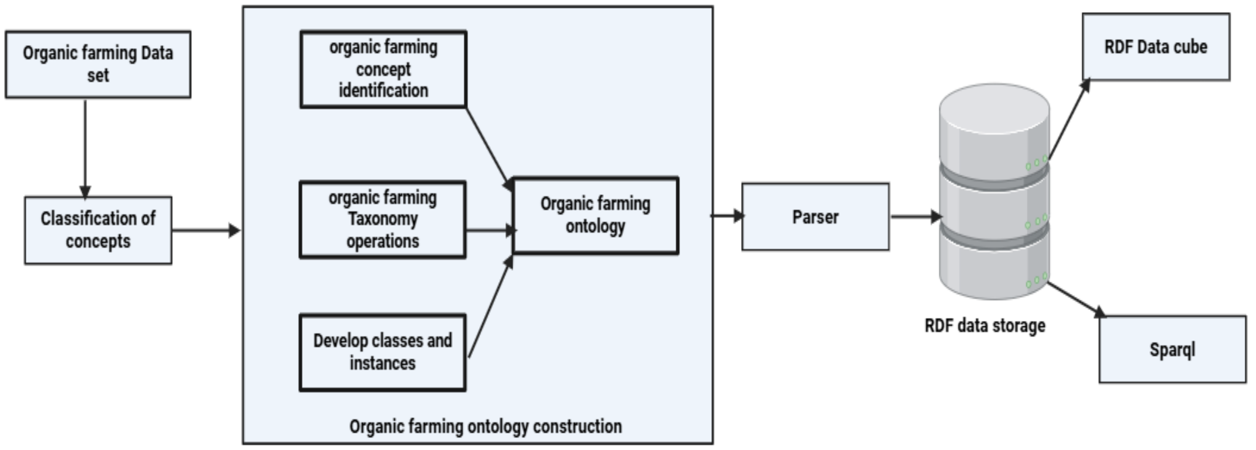

Fig. 1: Organic farming methodology

As shown in Fig. 1, a knowledge base is constructed from various sources of organic farming and stored as RDF-based data storage. The user poses queries on this knowledge base to retrieve information regarding farms. We have used the SPARQL query language to retrieve various data regarding organic crops. The results of SPARQL queries are compared with values in the data set to achieve correctness.

Organic Farming Ontology Development

Classes and Subclasses

We have developed organic forming otology by considering various concepts of organic farming, and each concept is modeled as a class. For classes, we created various sub-classes. The following table shows the classes and subclasses we have used in our ontology.

As shown in the above Table 1. We considered 11 categories of organic farming, and every category has sub-categories. These categories are represented as classes and subclasses, respectively, in the ontology. We construct the relationships between classes using object and data properties as discussed in the next section.

Data Properties

Data properties define the relationship between class instances and string literals, which are not objects. After defining the data properties, we create instances for classes using object property assertions and data property assertions. The following table shows some examples of data properties in the constructed ontology, along with some instances and their types (classes)

The above Table 2 demonstrates data properties of a few farms, like apple, broccoli, and Lettuce. Their types and their nutrient contents, soil pH, and water requirements are given in Table 2.

RDF Working

RDF stands for Resource Description Framework, used to exchange data on the web. It is a graphical data model that contains triples. The RDF triples will have the following format:

<subject, predicate, object>

A subject can be a resource, identified on the web using a Universal Resource Identifier (URI). A predicate is also a resource, identified by a URI that connects a subject and an object. An object can be a resource identified by a URI or can be a string literal. String literals are used to give names, numbers, and dates. Each string literal will have a type associated with it. Since URIs are long strings that need to be used in RDF documents, we can use a shorthand representation of a URI by declaring the namespaces. The RDF data needs to be transferred on the network. Semantic web technologies use standardization formats to make the RDF data readable. Various standardization formats exist, like:

i. N triples- Simplest notation which represents the data in triple format like <subject, predicate, object>. Everything except a string literal is represented using URIs. And strings are represented in quotes
ii. N3- N triples are simple, but a lot of restrictions are involved in output, like if in a graph, the same nodes are repeated, we need to include the same URI many times. N3 allows the use of short-hand URIs to represent repeated nodes using URI prefixes
iii. RDF/XML- The original description of the W3C recommendation specifies using RDF/XML to specify RDF data. It became less popular because it is difficult to read due to its abbreviated structure
iv. RDFa- It is not a pure serialization format; it is used to annotate web pages with RDF data. RDFa provides an idea to mix human-readable data and machine-readable data together. This standardization method adds rich semantic annotations to XHTML content

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v. Turtle- Turtle serialization method allows writing RDF graphs in compact and natural text forms and uses common abbreviations for repeated patterns. Turtle stands for "Terse RDF triple Language"

Sparql

SPARQL is a query language used to retrieve and manipulate RDF data. The SPARQL query has the following format:

```
        PREFIX: URI
        Select ? variable
        Where
{
                <subject predicate object>
}
```

In the select clause of the query, the variable represents data that needs to be retrieved. And in the where clause, we specify triples and variables on which the query will be answered.

Proposed RDF Model for Ontology Development

We propose an RDF model that is based on a constructed ontology AGROVAC, which provides a knowledge base for agriculture, animals, and vaccination-related concepts (Roussey et al., 2010b). AGROVAC is developed by the Food and Agriculture Organization (FAO) of the United Nations. Based on this ontology, we have created our ontology by considering various concepts widely used in organic farming data, object properties with data, and object properties. We have created some instances for classes. As shown in Figure 2. Organic farmers and users retrieve the required information regarding organic crops by interacting with the ontology through a semantic graphic search interface. The users' queries will be converted to SPARQL queries and posed on the knowledge base, which returns the matched outputs as results to the end user through a semantic interface.

Parser Implementation

RDF parser takes the user queries and breaks them down into small words known as lexemes. These lexemes will be posed in the form of a SPARQL query on the knowledge base. If lexemes are not as the terms in the Knowledge base, compilation errors occur. Hence, we use the terms in the knowledge base for creating queries.

Graphical Representation of the Developed Ontology for Organic Farming

A constructed ontology can be represented as a graph. The rectangles represent the classes, and the connecting lines represent the relationship ps between classes. The graph in Figure 3 is generated using protégé's OWLviz tab.

Data Parsing and Ontology Updating

We can update the ontology by passing queries and by directly updating through protégé platform. We have updated our ontology through protégé by adding instances, classes, data, and object properties. And parse the ontology by running HermiT reasoner, which synchronizes the ontology as it is updated. Reasoner returns errors if the ontology is not correctly updated. If ontology is correctly parsed, the following comments in the log will be printed.

```
INFO  15:17:21  ------------------------------ Running Reasoner ------------------------------
INFO  15:17:21  Pre-computing inferences:
INFO  15:17:21      - class hierarchy
INFO  15:17:21      - object property hierarchy
INFO  15:17:21      - data property hierarchy
INFO  15:17:21      - class assertions
INFO  15:17:21      - object property assertions
INFO  15:17:21  Ontologies processed in 255 ms by HermiT
```

If the ontology is updated wrongly, i.e., with incorrect data and object properties, the ontology becomes inconsistent. When we synchronize an inconsistent ontology, HermiTreasoner will generate a prompt along with an explanation showing the inconsistent ontology. Following Figure 4 is an example prompt that was generated when we gave wrong data properties for banana.

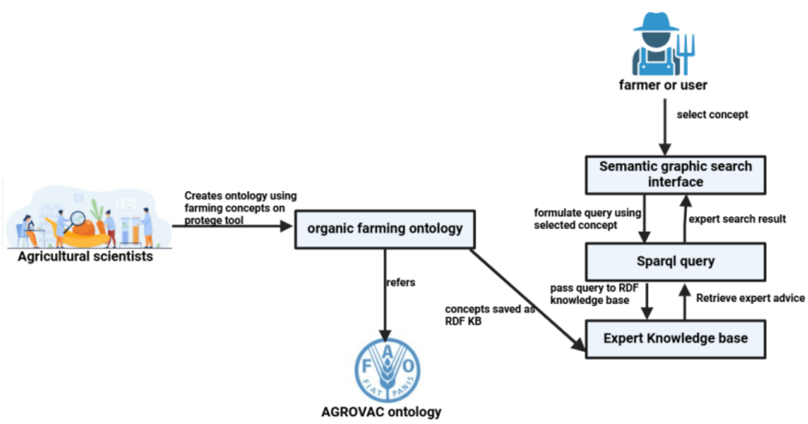

Fig. 2: Proposed Model

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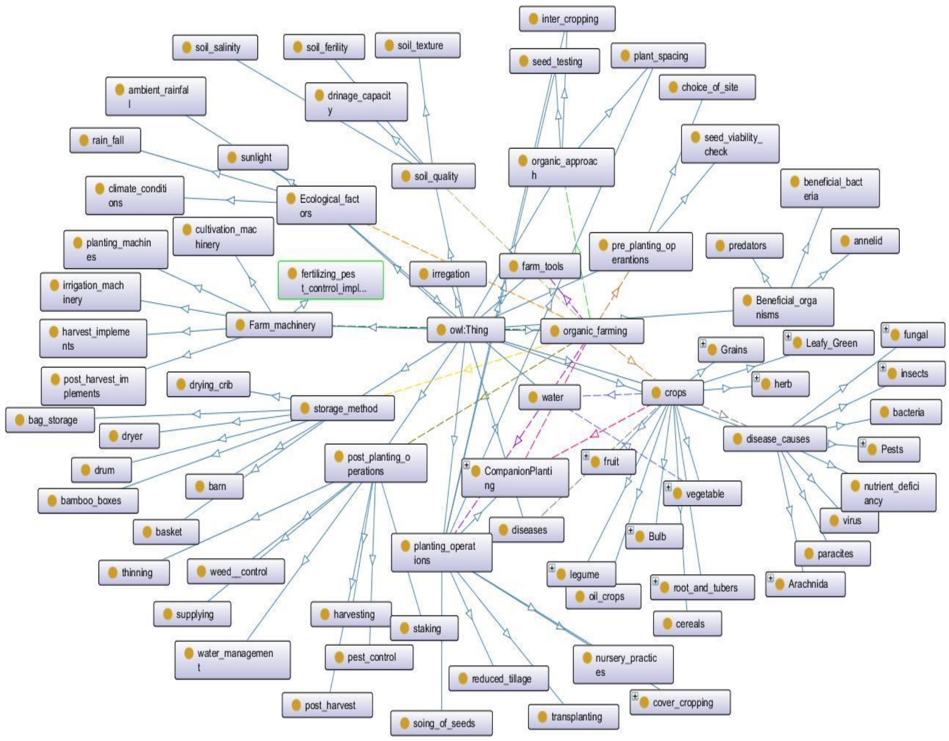

Fig. 3: Graphical representation of Ontology

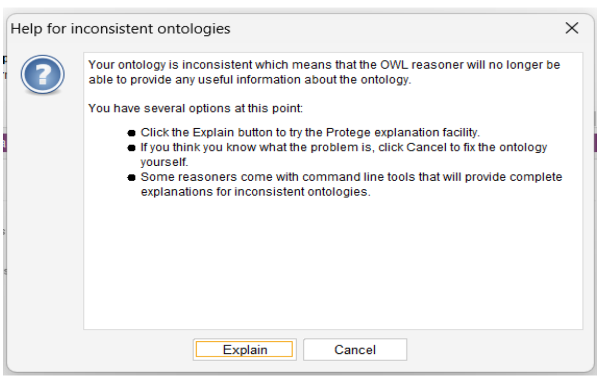

Fig. 4: Data Parsing and Ontology Updation

Results and Discussion

This part assesses ontology-based knowledge management with an eye toward needs and chores guided by the involvement of stakeholders. To reach the aims of this study, we have described the classes' validation gathered into the ontology. Thus far, the outcome moves from the framework for computing research and ontology-based approach to a web-based repository management system for organic farming. If ontology allows consistent answers to practical questions, it can be really important. Some code snippets in this part act as the outcome of findings for ontological validation and development. HermiT and Protégé are the instruments used for building and investigating the organic agricultural ontology. The modular nature of the protégé editor provides basic capabilities and several plug-ins depending on what has to be done.

For this endeavor, a protégé plug-in targeting OWL and RDF was selected; HermiT was used to monitor consistency and provide queries to confirm validity. DL query language was the translation tool for the questions. By presenting cases of the competent questions from the DL query interface, the competency of the Organic farming ontology to respond to user inquiries was evaluated. A colleague who specializes in semantic technologies and an organic farmer from the university where the study was done validated it. From this, it was confirmed that the search produced ideal responses for every question. Figure 3 shows the DL query on actions related to planting. While the ontology was consistently shown by the subclasses and instances created by it, the onto-graph shows the link between the several agricultural activities shown in Figure 3, and the subclasses of organic farming. After constructing the ontology, we executed SPARQL queries by considering a sample data set. We retrieved various information from the ontology as a result of SPARQL queries. The following Figs. 4-14 show the results for various queries posed on the ontology.

Query for finding the nutrient content of the tomato.

Q1: Query for finding the nutrient content of the tomato

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/mdgulzar/ontologies/2025/0/organic_farming#>
SELECT ?Nutrient_Conent_of_Tomato
        WHERE {:tomato :hasSoilpH ?p
        BIND(str(?p) AS ?Nutrient_Conent_of_Tomato)
}
```

Nutrient_Conent_of_Tomato
"6.5"

Fig. 5: Query Result to display the Nutrient contents of Tomato

Q2: Query for finding soilpH of tomato

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/mdgulzar/ontologies/2025/0/organic_farming#>
SELECT ?SoilpH_of_Tomato
        WHERE {:tomato :hasSoilpH ?p
        BIND(str(?p) AS ?SoilpH_of_Tomato)
}
```

SoilpH_of_Tomato
"6.5"

Fig. 6: Display the soil pH of the tomato

Q3: Query for finding units of water requirement for tomato

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/mdgulzar/ontologies/2025/0/organic_farming#>
SELECT ?Water_requirement_for_tomato
        WHERE {:tomato :requires_water ?p
        BIND(str(?p) AS ?Water_requirement_for_tomato)
}
```

Water_requirement_for_tomato
"30"

Fig. 7: Display the water requirements of the tomato

Q4: Query for finding insects affecting the tomato plant

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/mdgulzar/ontologies/2025/0/organic_farming#>
SELECT ?Affecting_insect_for_Tomato
        WHERE
        {
                :tomato :affected_by ?Affecting_insect_for_Tomato
        }
```

Affecting_insect_for_Tomato
aphid

Fig. 8: Display affecting the insect for the tomato

Q5: Query for finding the required planting machinery for tomato plants

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/mdgulzar/ontologies/2025/0/organic_farming#>
SELECT ?Planting_machines_for_Tomato
        WHERE { :tomato :requires ?Planting_machines_for_Tomato}
```

Planting_machines_for_Tomato
transplanter
irregation_system
weeder
tiller
mulcher

Fig. 9: Display planting machines for tomato.

Q6: query for finding the planting machinery required for rice

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/mdgulzar/ontologies/2025/0/organic_farming#>
SELECT ?Planting_machinery_for_rice
        WHERE { :rice :requires ?Planting_machinery_for_rice}
```

Planting_machinery_for_rice
paddy_transplanter
tractor
tiller
rice_precision_drill
combine_harvester

Fig. 10: Display planting machines for rice

Q7: Query for finding plants that are affected by cabbage worms

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/mdgulzar/ontologies/2025/0/organic_farming#>
SELECT ?Plants_afftected_by_Cabbage_worm
        WHERE { ?Plants_afftected_by_Cabbage_worm :affected_by :CabbageWorm}
```

Plants_afftected_by_Cabbage_worm
Broccoli
Cabbage

Fig. 11: Display Plant Affected by Cabbage worm

Q8: Query for finding ecological factors influencing barley plants

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/mdgulzar/ontologies/2025/0/organic_farming#>
SELECT ?Barley_influenced_by_Ecological_Factors
        WHERE { :barley :influenced_by ?Barley_influenced_by_Ecological_Factors}
```

Barley_influenced_by_Ecological_Factors
Rainfall_changes
rising_temparatures
Higher_carbon_dioxide_concentrations

Fig. 12: Display Barley influenced by Ecological Factor

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Q9: Query for finding storage mechanisms used for storing cabbages

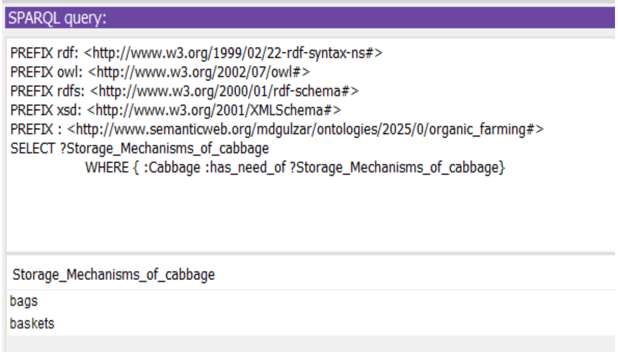

Fig. 13: Display Storage Mechanisms of cabbage

Q10: Query finding irrigation machinery required for apple farms

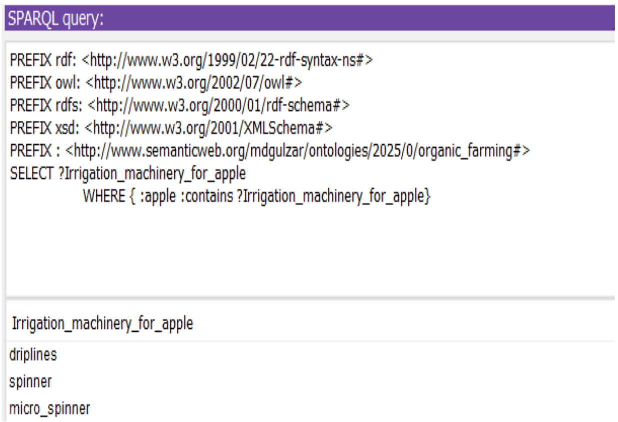

Fig. 14: Display Irrigation Machinery for Apple

Validation

We evaluated our model on a dataset of 121 organic farming instances, classified into 15 unique farm types. The model was validated using SQL query comparison and assessed with a Support Vector Machine (SVM) classification algorithm. The model achieved an accuracy of 76%, correctly classifying 28 out of 37 test samples. Several classes, such as Class 0, 1, 3, 4, 8, 9, 10, 13, and 14, achieved perfect scores of 100% across precision, recall, and F1-score, indicating highly reliable predictions for those categories. Table 4 shows the achieved performance metrics.

From Table 4, we got 76% accuracy and 71% Macro Average, which is the unweighted average of metrics like precision, recall, or F1-score across all classes. The weighted average, which is the performance of each class proportional to its instances, is 70%, which indicates good overall and per-class performance. The performance of our classification model can be shown as in the following Fig. 15 of the confusion matrix.

Table 4: Performance metrics computed on SVM

Metric	Score
Accuracy	0.76
Macro Avg (F1)	0.71
Weighted Avg (F1)	0.7

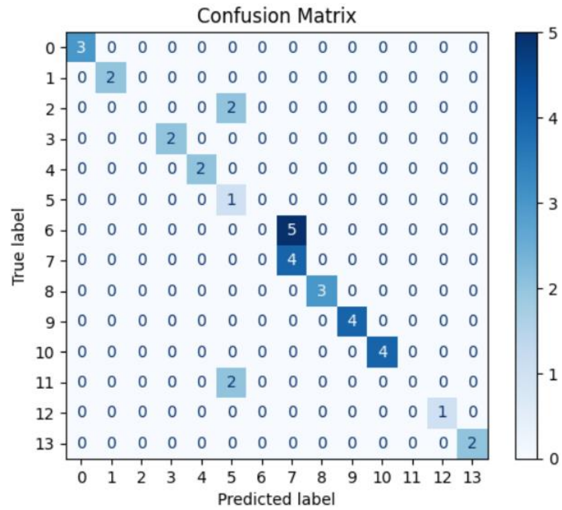

Fig. 15: confusion matrix

In the above figure, the Y-axis represents the correct categories, and the X-axis represents categories that our model predicted. From the figure, the main diagonal represents correct predictions from the figure cell (0,0), which says that for class 0, we have 3 data points, and our model also predicted them as they belong to class 0. Same as for cell (1,1), which is predicted as 2 data points belong to class 0, and so on. The values in the off-diagonal represent incorrect predictions. From the figure, we can see that we have a high number of correct predictions.

Conclusion

This paper focuses on creating an ontology-based knowledge management system tailored for organic agriculture, serving as a structured platform to disseminate essential agricultural insights to farmers and establish a concept-driven knowledge framework that efficiently organizes and distributes information about organic farming. A comprehensive literature review was performed to gather data on organic farming processes, which laid the groundwork for developing the ontology-based system. The Protégé OWL editor was employed to construct the knowledge repository. Ultimately, this model facilitates the timely distribution of information to farmers, reducing stress and enhancing their confidence in cultivating new crops. This support aids in converting implicit knowledge into explicit knowledge, which can significantly benefit organic farming practices. Additionally, it is expected to promote knowledge sharing and reuse within the organic farming community. The key findings of this research advocate for the timely exchange of information and the reusability of organic farming practices. The availability of timely information is crucial for the success of organic farming operations. This approach addresses the previous lack of accessible information that hindered the adoption of organic agriculture and promotes self-learning among farmers in regions where extension agents are not readily available. The ontology interface, developed using Protégé, facilitates the retrieval and reuse of the knowledge repository and database updates. In the future, the system needs to be developed into a comprehensive software package that can be downloaded and installed for self-training and knowledge acquisition in the organic farming field. Furthermore, usability testing with a larger group of users is yet to be conducted. The integrated knowledge retrieval system will be expanded into a substantial software package, followed by the implementation of usability, acceptance, and observational studies. Subsequently, a longitudinal study will be conducted over three to five years using economic dimensions through contingent valuation. The foundational reference ontology, derived from the architectural framework, can be further extended to support the development of mobile applications for organic farming. Concurrently, with the deployment of the mobile application, potential validity threats will also be addressed.

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Author's Contributions

All authors equally contributed in this work.

Ethics

The work described in this article is original research and represents a novel implementation using Semantic Web technologies. We attest that this manuscript has not been published elsewhere and is not currently under consideration by any other journal.

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